



Adapting to Climate Variability, Thresholds, and Extremes in the Southwest

The Climate Assessment for the Southwest (CLIMAS)

June 1, 2014 – May 31, 2015

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2014-15 CLIMAS TEAM

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Research Affiliates: Tim Brown, Julie Brugger, Julia Cole, Zack Guido, Katharine Jacobs, Diana Liverman, Alison Meadow, Kiyomi Morino, Jeremy Weiss

Climate & Society Fellows: 2014 – Chris Guiterman, Ling-Yee Huang, Rebecca Lybrand, Sarah Truebe; 2015 – Christina Greene, Valerie Rountree, Eric Magrane, Bhuwan Thapa

NEW AREAS of FOCUS and PARTNERSHIP

Southeast Arizona Agricultural Weather and Climate Working Group

CLIMAS Investigators: M. Crimmins, J. Weiss

The University of Arizona Cooperative Extension and the National Weather Service in Tucson developed a working group focused on engaging the agricultural community of Southeast Arizona. The working group is assessing information needs, providing training and technical support, conducting applied research, and developing new decision support tools.

Importance: Orchards and vineyards in southeast Arizona represent an important and growing agricultural industry in the region and are especially sensitive to weather and climate extremes like freeze events, hail, wind, floods and drought. The local NWS office had interest in forming a stronger partnership with the agricultural community in the region and approached UA Cooperative Extension and CLIMAS to help facilitate this interaction.

Additional support provided by the US Dept. of Agriculture Southwest Regional Climate Hub.

Exploring the Use of Climate and Remote Sensing Data to Support Drought Monitoring Across the Southwest U.S.

CLIMAS Investigators: M. Crimmins, J. Weiss

A new effort supported by a recent NOAA-SARP/NIDIS grant spurred the development of tool called ‘DroughtView’ which combines cutting edge online geovisualization tools with derived remote sensing products, targeted at detecting drought conditions. DroughtView builds on the success of a precursor effort called RangeView, which was developed with the guidance of agriculturists and resource managers with a need for environmental monitoring data. The tools in DroughtView are currently being used to monitor biweekly changes in land surface greenness conditions as a proxy for drought impacts at very fine spatial scales across the Southwest U.S.

Importance: Drought monitoring across the southwest U.S. is a challenging task given complex topography, seasonal climate, and sparse monitoring networks. Exploring the use of remote sensing imagery to support drought monitoring provides an important complementary monitoring tool for resource managers, farmers, ranchers and decision makers.

Additional support provided by NOAA Sectoral Applications Research Program and National Integrated Drought Information System.

Arizona’s Views on Climate Change

CLIMAS Investigators: G. Garfin, J. Overpeck

Arizonans have long dealt with high temperatures and limited water resources, and climate change may increase the magnitudes of these challenges by causing increases in heat and the severity and frequency of droughts. Understanding how the public views climate issues is of

considerable interest to a wide range of people, including policy makers, resource managers, health officials, researchers, educators, and others. Although many national surveys have described climate change attitudes, these studies have interviewed only small samples of Arizona residents and have yet to explore in depth the views of state residents. This project summarizes the results of a survey of public opinion that was commissioned by the University of Arizona and Stanford University to provide a better understanding of how the Arizona public views this issue.

Importance: We work in a culturally diverse, socially heterogeneous, and politically charged landscape. Knowing more about our stakeholders can help us provide the appropriate climate services, and provides us insights about science policy barriers and opportunities.

Additional support provided by The University of Arizona Institute of the Environment and Stanford University.

Western Adaptation Alliance – A Collaboration Project for Adaptation and Resilience to Climate Extremes

CLIMAS Investigators: G. Garfin

This project is designed to assist regional urban network managers of the Western Adaptation Alliance (WAA) in communicating with key constituencies in their communities to broaden support for action on climate adaptation and to improve preparedness. Specifically, this involves (a) keeping an inventory of major extreme events involving temperature extremes, flooding, drought, fire, and wind for each WAA city and across the region, (b) recording specific actions taken following those events, (c) developing narratives for each extreme impact, and (d) creating a toolkit for the highest priority impact—extreme heat events.

Importance: Communicating about climate change can be tough in politically conservative states. Alternative messaging about climate variability and resilience can provide a means to communicate effectively to motivate voters and elected officials to endorse and act to increase preparedness for climate extremes.

Arizona Business Resilience Initiative - An Initiative To Support Arizona's Business Community In Managing Climate Risk

CLIMAS Investigators: B. McMahan, G. Owen

The Arizona Business Resilience Initiative (ABRI) is focused on developing a methodology for assessing business opportunities and managing risks to their operations associated with climate change and climate variability. Working with business partners, this project aims to answer two questions: (1) Based on current state-of-knowledge in climate change impacts and vulnerability assessment, what are the most probable impacts on the company's operations and projections due to climate change? (2) With an understanding of the possible impacts, what are actions that can be taken to anticipate or mitigate these risks, or to position the company to take advantage of new opportunities that anticipate and adapt to climate change?

Importance: This project will build new avenues for engagement between the University of Arizona and the private sector. It applies university resources and expertise to develop a replicable framework with participating businesses that will significantly enhance their ability to react and respond to climate risks specifically, and the private sector's resilience to global changes more generally.

Additional support provided by The University of Arizona Office for Research and Discovery.

Building A Regional Climate Database: Integrating Climate Data into Ecological Analysis, Monitoring, and Restoration

CLIMAS Investigators: B. McMahan, M. Crimmins

This project is in collaboration with regional ecological analysis, monitoring, and restoration groups to facilitate their use of climate data in their regular operations, as well as their long-term planning/analysis. The impact of climate variability and change, especially as temperature and precipitation regimes shift, (resulting in differing time of onset for spring, reduced snowpack, etc.), necessitates a better understanding of these shifts, as well as the implications these changes have for practices of ecological management and restoration.

Importance: This project addresses ecological and environmental issues that are linked to climate of the southwest, and opens up collaborations with new stakeholders/collaborators regarding analysis and mitigation of these changes.

RISA: An Organizational Ethnography

CLIMAS Investigators: A. Meadow

The RISA program was founded in 1995 as an experiment in the delivery of climate information to decision makers. This project applies organizational ethnographic methods to develop a comprehensive history of the program and a description of its structure and function. The 20-year anniversary of the RISA program is an excellent time to reflect upon how RISA was created and developed and what other boundary and climate service organizations can learn from RISA about how to structure their programs to optimize climate service delivery, collaborative knowledge development, and learning within the organizations.

Importance: Understanding how the broader RISA program was founded and has developed over the last 20 years, including how it currently functions, can provide us with valuable insights into how to build and maintain other climate services or climate-focused boundary organizations. This project was requested and funded by the Climate Program Office. Their goal was to have as comprehensive-as-possible history of the program to use in their offices.

SELECTED RESEARCH FINDINGS

Defining Ecosystem Water Needs and Assessing Impacts of Climate Change and Water Diversion on Ecosystems of the Upper Gila River in New Mexico

CLIMAS Investigator: G. Garfin

- Using a multi-model average, future annual temperature projections show increases in the upper Gila River Basin, on the order of 2-3°C (~3.6-5.4°F), with the highest increases in the summer and fall seasons.
- Using a multi-model average, future precipitation projections show decreases, with the largest decreases during the spring and summer.
- The projected five-model weighted average streamflow for the Gila River near Gila is a 6% decrease in water quantity (with a 15% median decrease in streamflow); for the Gila River near Virden it is an 8% decrease (15% median decrease); and for the San Francisco River at Clifton it is an 11% decrease (19% median decrease) for the time period 2041-2070 in comparison to the time period 1971-2000.
- Low flows are projected to decrease (get even lower) in the future, and very high flows are expected to increase (get even higher), even as overall streamflow is projected to decrease.

Sectoral Impacts of Drought and Climate Change

CLIMAS Investigator: G. Frisvold

- Colorado River Delta restoration requires permanent increases in base flows and periodic larger volumes of water for pulse flows. Although, pulse flows require more water, obtaining water for these may actually be easier than for base flows because water could be obtained through short-term leasing arrangements rather than permanent transfers.
- Through input analysis, researchers found that while agriculture supports about one in five jobs directly, because of linkages with the rest of the economy, agriculture supports one in four jobs in Yuma County. Changes in water rights or allocations to agriculture could potentially have significant impacts to the local economy.

Disentangling the Influence of Antecedent Temperature and Soil Moisture on Colorado River Water Resources

CLIMAS Investigators: C. Woodhouse, R. Brice

- Cool season precipitation is the most important driver of water year flow in the Upper Colorado River basin, overall explaining two thirds of the total variance, while March-July temperatures explain just 8%.

- However, when flow is greater or less than typically expected, given cool season precipitation, temperatures may be playing a role, of either exacerbating or ameliorating the effect of cool season precipitation on water year streamflow.

Adaptation Strategies for Water and Energy Sectors in the Southwest

CLIMAS Investigators: B. Colby, G. Frisvold, C. Woodhouse, G. Garfin, R. Klawitter, D. Duval, A. Clarke, T. Duffy

- Innovative features in programs to reduce crop irrigation, including new water banking initiatives, should be considered in the new phase of the Colorado River Basin System Conservation Program.
- Well-structured water banking programs can significantly reduce the regional economic damages from water supply shortfalls and should be a key feature of climate change adaptation.

Southeast Arizona Agricultural Weather and Climate Working Group

CLIMAS Investigators: M. Crimmins, J. Weiss

- The greatest temperature threshold concern to agricultural production in southeast Arizona is freezing because of the sensitivity of vineyard and orchard operations.
- The concern about freezing events increases through the spring as vegetation continues to grow and becomes more sensitive to a freezing event. This series of events occurred during winter and spring 2015.

Arizona's Views on Climate Change

CLIMAS Investigators: G. Garfin, J. Overpeck

- A large majority of Arizona residents believe that the world's temperature has been rising (74%), that it is at least partly caused by human activity (78%), and that it will continue to rise if nothing is done to stop it (75%). More than half believe global warming has caused more droughts and storms around the world as well as more forest fires and heatwaves in Arizona.
- More people believe that federal or state action to prepare for or reduce the effects of global warming would help the Arizona economy than the proportion who believes government action would hurt the state economy or have no effect.
- Generally, Arizonans' views on global warming are not substantially different from those of the U.S. as a whole. Responses to some questions indicate that Arizonans are more concerned that the impacts of climate change will hurt them personally (43% Arizona compared to 34% U.S.).

Climatic Sensitivities of Navajo Forestlands: Use-Inspired Research to Guide Tribal Forest Management

CLIMAS Investigators: C. Guiterman, D. Ferguson, C. Woodhouse, M. Crimmins

- Winter precipitation was the most important variable in controlling tree growth among plots in the Chuska Mountains. Summer temperatures and vapor pressure deficit were secondary.
- Among plots, landscape setting (slope steepness and aspect in particular) was the primary driver of variability. Trees growing on steep slopes with shallow soils and more southerly exposure were more affected by drought and increased temperatures. For managers, this means that those sites could be more likely to experience higher tree mortality in the future, while trees growing on more sheltered sites might be relatively more resilient to future climate extremes.
- Substantial diversity exists in the age structures of forest plots. This means that recruitment is ongoing and the range of tree ages present on the forest could help promote forest resilience in the future by maintaining tree dominance through drought episodes.

Fostering Conducive Conditions for Climate Assessments: Collaborative Scenario Planning and the Colorado River Basin Study

CLIMAS Investigators: G. Garfin, M. Hammersley

- People with greater participation and access to influence on the scenario planning process generally reported that the process met their needs and fostered the understanding of others, whereas people with less participatory power and access to influence generally reported that the scenario planning process was not as effective and did not meet their needs.

Climate Mitigation and Agriculture: Public Policy Education

CLIMAS Investigators: G. Frisvold, G. Camara, N. Puarattana-aroonkorn

- A cap and trade program with domestic agricultural offsets for carbon sequestration from tree planting may provide significant water conservation co-benefits. Because such a policy would act as a groundwater pumping tax, it would reduce agricultural water use significantly in the West.
- By reducing fertilizer use and retiring land in the Mississippi Basin, it could also contribute to reducing hypoxia problems in the Gulf of Mexico. While absolute pesticide and fertilizer use would decline nationally, some regions would experience significant increases in applications per acre. This means there could be potential 'hotspots' of chemical and fertilizer use in some watersheds.

OUTREACH ACTIVITIES

Southwest Climate Podcasts

CLIMAS Investigators: B. McMahan, M. Crimmins, G. Frisvold, B. Colby, D. Ferguson, G. Garfin, E. Huddleston, Z. Guido, R. Thomas

CLIMAS scientists discuss climate-related issues in monthly climate podcasts and special podcast series. The podcasts synthesize information from disparate sources and adds regional context for the Southwest. The podcasts also add insight to the discussions by bringing in latest climate science, covering climate-related topics with nuance but not shrouded in technical jargon. We have grown the audience of the SW Climate Podcast, expanded into two new podcast series, and explored new ways to distribute existing podcast series. This year we produced three podcast series plus one video podcast:

- *1075' – Shortage on the Colorado River* explores what the first ever shortage declaration on the Colorado River would mean to those living in the Southwest. 1075' refers to the elevation of Lake Mead – in feet above sea level – that serves as the trigger for shared shortage restrictions. While this has never happened before, after years of drought and ever-increasing demands on the river, the latest projections from the Bureau of Reclamation suggest the lake could drop below 1075' as soon as early 2015. In this series, we attempt to demystify the rules and regulations that govern water use on the Colorado River and discussed what it means to the people and sectors across Arizona when a shortage occurs. It was distributed on the CLIMAS list-serv, the CLIMAS blog, and on Twitter, FaceBook, and YouTube.
<http://www.climas.arizona.edu/research/1075-shortage-colorado-river-climas-podcast-series>
- *Southwest Climate Update – Mini Podcast* is a pilot podcast series that focuses on quick and timely reporting on important climate news and information. It emphasizes stories that relate to the Southwest, as well as climate related news, that illustrate the impact of climate on national or global scales. This podcast is also released as a video Mini-Podcast on the CLIMAS YouTube Channel. <http://www.climas.arizona.edu/podcast/southwest-climate-update-may-1-2015>.
- *Speaking of Climate...* is a pilot podcast series that includes conversations with researchers and stakeholders about climate related issues. This podcast expands our focus broader than just the Southwest and takes advantage of the numerous people who work on climate science, communication, outreach, education, and engagement on a daily basis. Distributed on the CLIMAS list-serv, CLIMAS blog, Twitter, FaceBook, and YouTube.
<http://www.climas.arizona.edu/podcasts/speaking-climateconversations-about-climate-science-society>
- The video podcasts are mostly derived from the SW Climate Podcast. Images, maps, and video supplements illustrate the concepts discussed in the podcast. It is part of an integrated social media outreach strategy to cross-publish podcast content. Numerous people have expressed interest in these videos, with numerous interactions across social media.
<http://www.youtube.com/user/uacлимas>

Southwestern Oscillations: News, Information, & Commentary – CLIMAS Blog

CLIMAS Investigators: B. McMahan, M. Crimmins, G. Garfin, D. Ferguson, G. Frisvold, E. Huddleston, Z. Guido, G. Owen

Southwestern Oscillations is a hub for news, information, & commentary about CLIMAS research & climate related issues. The blog is regularly updated with news and information on: CLIMAS research projects and publications; workshops, seminars, colloquia, and presentations; ongoing and completed outreach activities (e.g., podcasts, presentations, Southwest Climate Outlook); feature articles and summaries on climate research and climate related issues; and blog specific content such as “Notes from the Field” reports, and “Ask an Applied Climatologist”. <http://www.climas.arizona.edu/blog>

The Southwest Climate Outlook

CLIMAS Investigators: B. McMahan, G. Garfin, M. Crimmins, D. DuBois, E. Huddleston, Z. Guido

CLIMAS continued to produce the Southwest Climate Outlook (SWCO), a monthly publication that summarizes climate and weather information from disparate sources in nonscientific language for more than 1,600 people. Monthly issues are found here: <http://www.climas.arizona.edu/swco>.

SWCO content was also published online in Southwestern Oscillations (the CLIMAS blog). Content included SWCO Feature articles (<http://www.climas.arizona.edu/blog-category/4>) and climate summaries and outlooks (<http://www.climas.arizona.edu/blog-category/2>). This year, a number of interactions occurred across social media regarding SWCO content. In particular, key points from SWCO articles have been tweeted/shared on social media by members of our regional network. This effort has also begun to expand to larger networks via tweets/retweets outside of our own network of followers.

General Climate Outreach Presentations

CLIMAS investigators are often invited to give presentations to broad audiences regarding climate variability and climate change in the Southwest. These presentations are about climate in general, and are counted separately from research talks about CLIMAS research. This year these presentations were given by:

- J. Overpeck – 8 presentations
- M. Crimmins – 28 presentations
- G. Garfin – 25 presentations
- C. Woodhouse – 2 presentations

KEY PUBLICATIONS

Liverman, D., **G. Garfin**, S. Doster, K. Bao, F. Gladstone, J. Krosnick, B. MacInnis, and **J. Overpeck**. 2015. Arizona's Views on Climate Change - Executive Summary. Institute of the Environment, Tucson, AZ. <http://www.environment.arizona.edu/sites/default/files/climate-survey/ExecutiveSummary.pdf>

This report summarizes the results of a public opinion survey that was commissioned by the University of Arizona and Stanford University to provide a better understanding of how the Arizona public views climate change. Results improve our understanding of stakeholder attitudes on a key climate and environmental issue.

Ault, T., J. Cole, **J. Overpeck**, G. Pederson, and D. Meko. 2014. Assessing the risk of persistent drought using climate model simulations and paleoclimate data. *Journal of Climate* 27(20): 7529-7549. <http://dx.doi.org/10.1175/JCLI-D-12-00282.1>

Projected changes in global rainfall patterns will likely alter water supplies and ecosystems in semiarid regions during the coming century. Instrumental and paleoclimate data indicate that natural hydroclimate fluctuations tend to be more energetic at low (multidecadal to multicentury) than at high (interannual) frequencies. State-of-the-art global climate models do not capture this characteristic of hydroclimate variability, suggesting that the models underestimate the risk of future persistent droughts.

This article received media attention after it was published in early 2015, including:

- Osgood, M. 2014. Global Warming Increases Chance of US 'Megadrought'. September 2, 2014. <http://www.reportingclimatescience.com/news-stories/article/global-warming-increases-chance-of-us-megadrought.html>
- Kille, L. 2015. Climate change and the growing risk of 'megadroughts' in California and the southwestern United States. *Journalist's Resource*. April 14, 2015. <http://journalistsresource.org/studies/environment/climate-change/climate-change-risk-megadrought-united-states>
- McClellan, J. 2014. Megadroughts might be coming to the Southwest. *Tech Times*. August 28, 2014. <http://www.techtimes.com/articles/14306/20140828/megadroughts-are-coming.htm>

Meadow, A., D. Ferguson, Z. Guido, A. Horangic, G. Owen, and T. Wall. 2015. Moving Toward the Deliberate Coproduction of Climate Science Knowledge. *Weather, Climate, and Society* 7(2): 179-191. <http://dx.doi.org/10.1175/WCAS-D-14-00050.1>

Coproduction of knowledge is believed to be an effective way to produce usable climate science knowledge through a process of collaboration between scientists and decision makers. This article presents five approaches to collaborative research to help structure the process of coproduction. By using established collaborative research approaches, scientists can be more effective in learning from stakeholders, more confident when engaging with stakeholders because there are guidelines to follow, and can assess both the process and outcomes of collaborative projects, which will help the whole community of stakeholder-engaged climate scientists learn about the coproduction of knowledge.

This article sparked an email exchange of feedback between members of several Climate Science Centers in June 2015.

Bark, R., **G. Frisvold**, and K. Flessa. 2014. The role of economics in transboundary restoration water management in the Colorado River Delta. *Water Resources and Economics* 8: 43-56. <http://www.sciencedirect.com/science/article/pii/S2212428414000516>

This article illustrates the potential of fundamental economic concepts (opportunity cost, marginal analysis, and Pareto-improving compensation) in developing options to provide ecological restoration flows to the Colorado River Delta. It addresses the needs of stakeholders desiring Delta restoration with policy options and feasibility analysis to achieve that objective.

Colby, B., G. Frisvold, and M. Mealy. 2015. Managing Climate Risks Through Water Trading. In K. Burnett et al. *Routledge Handbook of Water Economics and Institutions*. New York: Routledge.

This chapter examines the potential for voluntary water trading and improved forecasting to mitigate water supply risks from climate risk in the Lower Colorado River Basin. For stakeholders, it illustrates how seasonal summer weather forecasts can facilitate short-term water transfers and mitigate supply risks.

Frisvold, G. 2015. The economic contribution of agriculture in Yuma County. In W. Noble. *A Case Study in Efficiency – Agriculture and Water Use in the Yuma, Arizona Area*. Yuma, AZ: Yuma County Agriculture Water Coalition. <https://wrrc.arizona.edu/case-study-in-efficiency>

This chapter applies input-output analysis to both direct and indirect contributions agriculture to Yuma's economy, including output, value added, and jobs. Stakeholders in Yuma (both agriculture and local government officials) are concerned that drought and Colorado River shortages will increase pressure to alter property rights to water in Yuma, negatively affecting agriculture and the county economy as a whole. This work was in direct response from stakeholder requests for analysis to respond to Bureau of Reclamation planning documents.

Díaz-Caravantes, R. and **M. Wilder**. 2014. Water, Cities and Peri-Urban Communities: Geographies of power in the context of drought in northwest Mexico. *Water Alternatives* 7(3): 499-517. <http://www.water-alternatives.org/index.php/alldoc/articles/vol7/v7issue2/261-a7-3-4/file>

This article examines geographies of power of the urban-rural interface in Sonora, Mexico. It argues that urban water augmentation strategies reveal a distinct set of urban-peri-urban relations of unequal social power, in which peri-urban water resources are transferred to urban areas. This finding reflects the water demands of powerful, politically connected urban populations and large irrigation districts over the last three decades (1981-2010) in northwest Mexico. During this time period, peri-urban small-scale communal farmers, or ejidatarios, lost access to their water as it was moved or used to supply the needs of Hermosillo's expansion.

SELECTED APPLICATIONS of CLIMAS WORK

Defining Ecosystem Water Needs and Assessing Impacts of Climate change and Water Diversion on Ecosystems of the Upper Gila River in New Mexico

CLIMAS Investigators: G. Garfin

This project examined the historic and projected records of climate factors for the Southwest, with a focus on the upper Gila River Basin in New Mexico. This work addresses the climate change information needs of stakeholders in the Gila River Basin in New Mexico. Stakeholders include multiple NGOs, private sector consultants, citizens in the Upper Gila River Basin, and state and federal agencies that are concerned with New Mexico's allocation of its Gila River allotment.

The results of this research were written up in the *Gila River Flow Needs Assessment – A report by The Nature Conservancy* (<http://nmconservation.org/Gila/GilaFlowNeedsAssessment.pdf>). Results suggest that water should not be diverted from the Gila River due to temperature, precipitation, and streamflow projections. Several responses, reviews, and critiques of this chapter were written, including a review by David Gutzler. A written chapter reviews were submitted as public testimony to the New Mexico Interstate Stream Commission. Despite the findings of this research, the NM Interstate Stream Commission voted to divert water from the Gila River.

“The New Mexico Interstate Stream Commission on Monday said “yes” to a controversial proposal to divert water from the Gila River for use in southwestern New Mexico farms and cities – but with reservations. The commission agreed to formally notify the U.S. Department of Interior that it wants to proceed with a project that would divert water from the Gila during times of high flow, building reservoir storage so that it can then be piped for as yet unidentified uses.” (From Fleck, J. 2014. Stream commission votes to divert water from Gila River. *Albuquerque Journal*. November 24, 2014.)

Exploring the use of climate and remote sensing data to support drought monitoring across the Southwest U.S.

CLIMAS Investigators: M. Crimmins, J. Weiss

DroughtView combines geovisualization tools with remote sensing products to detect drought conditions. The DroughtView tool was used in a local drought assessment workshop held in Wilcox, Arizona in February 2015. It served as a key piece of information to help the National Resources Conservation Service, Bureau of Land Management, and U.S. Forest Service range managers determine drought conditions and Farm Services Agency drought disaster assistance eligibility.

To decide where grazing areas were affected by drought in 2014 across southeastern Arizona, rangeland management and FSA personnel met with University of Arizona Cooperative Extension representatives in early 2015 to discuss a suite of information sources. By integrating maps of difference-from-average greenness with on-the-ground observations of rangeland conditions, meeting participants were able to determine the extensiveness of recent drought conditions and delineate grazing areas where drought-induced losses occurred and financial assistance is justified.

Adaptation Strategies for Water and Energy Sectors in the Southwest

CLIMAS Investigators: B. Colby

Water experts from across the western U.S. wrote a review of Colorado's Draft Water Plan. The resulting report provided specific recommendations for the Colorado Water Plan. Based on the report's recommendations, the following changes to the Colorado Water Plan were noted as of May 2015:

"With regard to recommendation 1, Ch. 10 will be retooled as an action plan. With regard to recommendation 2, the aforementioned action plan will describe incentives to water providers to develop projects and methods that are in line with Colorado's Water Plan. With regard to recommendation 3, the watershed section will clarify the need for watershed and stream management plans and the criteria written for these grant programs will include the recommendations provided by the commenter. With regard to recommendation 4, the maintenance and improvement of existing infrastructure is an important part of Colorado's water future and is an aspect of Section 6.5. With regard to recommendation 5, Colorado's Water Plan will update actions related to climate change including the monitoring of climate related conditions and the continuation of the climate change technical advisory group to help identify water uses that are most at risk."

Report citation: MacDonnell, L., R. Benson, B. Colby, R. Glennon, B. Udall, and C. Wilkinson. 2015. Navigating a Pathway Toward Colorado's Water Future: A review and recommendations on Colorado's draft Water Plan. Boulder, CO: Getches-Wilkinson Center for Natural Resources, Energy, and the Environment, University of Colorado Law School.

PROGRAM EVALUATION EFFORTS

The CLIMAS program evaluation project has three overarching goals:

- Improve CLIMAS by measuring the impact of specific elements of the program and feeding those results back into program operations.
- Demonstrate the value of CLIMAS by assessing who values the program and how.
- Develop a set of metrics that allow us to identify the impacts and influence CLIMAS has.

The four elements included in this evaluation are:

A) Outreach; B) Graduate and Undergraduate Training; C) Advancing Science Knowledge (e.g., peer-reviewed publications); and D) Use-Inspired Science and Decision Support

The broader *research questions* we propose to answer through program evaluation include:

- *Outreach*: How does CLIMAS outreach influence people's understanding of climate and/or climate impacts in the Southwest? How does CLIMAS outreach foster collaborative interactions between researchers and practitioners?
- *Graduate and Undergraduate Training*: What impact does CLIMAS have on future generations of researchers and practitioners?
- *Advancing Science Knowledge*: How and in what areas does CLIMAS advance scientific knowledge?
- *Use-Inspired Science and Decision Support*: Where on the spectrum of participatory research approaches do CLIMAS projects fit? How are the principles of participatory research applied to CLIMAS research? How does CLIMAS influence people's behavior (including decision making)?

Examples of metrics we are collecting for the program evaluation include:

Outreach: Interactions with media (newspaper, video, TV, etc., that is authored or produced by someone else); Online Contributions (produced by CLIMAS PIs for podcasts, blogs, news outlets, etc.); Presentations (including questions about the audience, why PIs decided to give the presentation, etc.); Social Media (substantive interactions on social media outlets)

Graduate and Undergraduate Training: Numbers of students enrolled in CESD program, applying for CLIMAS Fellowship, attending talks, employed as GRAs; Depth of knowledge about use-inspired science approaches.

Advancing Knowledge: Publications (peer-reviewed and not-peer-reviewed); Use of publications by academia (citations); Categorizing where articles are published (across disciplines); use of publications by stakeholders (applications).

Use-Inspired Science and Decision Support: Variable for each project. Interviewed each PI about their research, using logic model framework. Focus on outputs, and short- and medium-term outcomes. Most metrics in this section will be gathered from interviews with the intended stakeholders for each output.

APPENDIX: PUBLICATIONS

- Bark, R., G. Frisvold, and K. Flessa. 2014. The Role of Economics in Transboundary Restoration Water Management in the Colorado River Delta. *Water Resources and Economics* 8: 43-56. doi:10.1016/j.wre.2014.10.006
- Brown, H., A. Comrie, J. Tamerius, M. Khan, J. Tabor, and J. Galgiani. 2014. Climate, Windstorms, and the Risk of Valley Fever (Coccidioidomycosis). In E. Choffnes and A. Mack, *The Influence of Global Environmental Change on Infectious Disease Dynamics*. Washington, DC: The National Academies Press: 266–282.
- Brugger, J. and M. Crimmins. 2014. Designing Institutions to Support Local Level Climate Change Adaptation: Insights from a Case Study of the U.S. Cooperative Extension System. *Weather, Climate, and Society* 7(1): 18-38. doi:10.1175/WCAS-D-13-00036.1.
- Clarke, A. 2015. *Come Hell Or High Water Prices: A household-level analysis of residential water demand*. Master's Thesis. Department Of Agricultural And Resource Economics, University of Arizona.
- Colby, B., G. Frisvold, and M. Mealy. 2015. Managing Climate Risks Through Water Trading. In K. Burnett et al., *Routledge Handbook of Water Economics and Institutions*. New York: Routledge.
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